Ecosystem-Based Adaptation Strategies for Flood Mitigation in Lake Naivasha Catchment, Kenya

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DOI: https://doi.org/10.51867/ajernet.5.4.161

ABSTRACT

Several factors are affecting the hydrological cycles but human activities have played a major role in the experienced hydrological changes. Some human activities such as agriculture and industrialization have contributed to the change in the water balance through the extraction of water, construction of impoundments and climate change factors. The fluctuations in the water levels have effects on the ecosystem, as they interrupt the natural and breeding habitats of some animals such as the fish and other wildlife and the germination of coastal plants. Some of the methods used to mitigate floods in Kenya include the; establishment of early warning systems, establishment and improvement of infrastructure such as flood-resistant roads and bridges in affected areas, and community-driven initiatives such as the participatory mapping of flood-prone areas. Based on the Socio-Ecological Systems (SES) Theory, this study has incorporated a multi-faceted design of field surveys, observations, and stakeholder interviews to meet the following objective; to determine the ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment. With a target population of 29,190, a sample size of n=395 comprising of stakeholders in different areas including fishermen, farmers, tour guides, and tourists and other residents was identified randomly and helped to collect data to determine the existing Ecosystem-based adaptation (EBA) strategies for mitigating floods in the catchment. The study employed a descriptive correlational method comprising of combined quantitative and qualitative approaches to comprehensively assess severity of floods in the Lake Naivasha catchment, identify the existing EBA strategies in the catchment and understand their effectiveness in mitigating floods in the catchment. Primary data was collected through structured questionnaires, key informant interviews, and focus group discussions. Descriptive analysis was used and this included a chi-square test used to analyze categorical variables to examine any significant differences between occupation and awareness of ecosystem-based strategies among participants. The findings of this study indicated that EBA strategies such as agroforestry and afforestation were the highly adopted non-structural strategies while soil conservation terraces and rain-water harvesting were the highly adopted structural strategies and were highly effective in mitigating the floods hence combating the impacts of climate change (Sustainable Development Goal 13) such as flood risks, improving water quality and enhancing community resilience in Lake Naivasha catchment. From the study, 77.75% of the participants reported that they had experienced observable positive changes in flood occurrence with most of the residents (81.87%) who use afforestation and agroforestry claiming to have observed a reduction in floods occurrence in the catchment. From the study, the highly adopted non-structural EBA strategies were afforestation and agroforestry due to their co-benefits and government support while the least were mulching and cover cropping due to insufficient knowledge on the application methods. The study recommends that more research should be done to understand other flood mitigation measures to help reduce the impacts of severe floods in the catchment, awareness creation among more community members regarding EBA strategies, their effectiveness in flood mitigation and how the community members can participate at the individual and community levels in adopting these strategies.

Key Words: Catchment, Ecosystem-Based Adaptation Strategies, Flood Mitigation, Flood Risks, Flood Severity

I. INTRODUCTION

The world responses to disasters and calamities have been highly advocated for with the rise in different disasters, calamities and pandemics such as floods and the most recent being Covid 19. The major types of floods are interlinked since the hydrological system is interconnected. For instance, fluvial floods negatively impact the surrounding where the river flows as it drains its water into larger water bodies. Pluvial floods on the other hand are highly experienced in urbanized areas and other areas independent of their proximity to water bodies (Muia et al., 2021). Coastal floods which may also be referred to as 'storm surge' affect large water bodies such as lakes, oceans and seas. All these types of floods have different impacts and therefore their mitigation and management strategies are different. The impacts of floods have been felt globally with the worst being deaths of people humans and animals and the destruction of property. The negative impacts of disasters on the livelihoods of individuals are more adverse compared to the positive ones (Rahman, 2014). Ecosystem-based approaches have been increasingly recognized globally as an important complementary strategy to flood management due to their cost-effectiveness, ecological benefits, and climate resilience. For example, South Africa implements rainwater harvesting systems to manage urban flooding and increase water security during dry periods. Wetland restoration, on a large scale, has also enhanced flood retention and biodiversity conservation in Bangladesh. They are in line with global trends linking nature-based solutions to environmental sustainability with disaster risk reduction. The increasing focus on EBA is rooted in its complementarity with climate adaptation frameworks, such as the United Nations' Sustainable Development Goals (SDGs), notably SDG 13 on climate action ((Muia et al., 2021).

There exist positive impacts of floods especially to the health of the vegetation on the floodplains. When there are floods, some species of animals are able to secure new breeding grounds while the rise in water levels enables the germination of different plants and also provide irrigation waters for agriculture. Despite the flood benefits, the negative impacts of floods are extreme which calls for immediate mitigation (Jonkman, 2005). Globally, floods account for approximately 47% of the disaster risks recorded in the past 20 years (Suhr & Steinert, 2022). The impacts of floods have affected about 2.3 billion people globally and recording about 43.5% death in 2019 (Suhr & Steinert, 2022). Floods contribute to the economic losses as it affects economic activities such as tourism, agriculture and fishing. The migration of wildlife from their natural habitats to human environment results in the increase in human-wildlife conflicts. There is displacement of people from the flooded settlements as well as the rise in the prevalence of water borne diseases (Muia et al., 2021). The rehabilitation of property and infrastructure destroyed by floods is costly, especially in the third world countries that depend on grant relief help.

Information obtained from different research findings has different anthropogenic, geological, and hydro-climatic explanations attributed to the causations of the rising water levels causing floods in different water bodies and urban areas. Some of the findings base their argument on tectonic plate movements, climate changes aspects such as increase precipitation in the areas, human activities such as over cropping, change in land use land cover (LULC), urbanization, settlement, and industrialization that has resulted in erosion causing siltation of the lake basins hence increasing the water levels among other theories (Herrnegger et al., 2021). There is no specific theory that has been proven to be the actual cause of the increased water level in the rift valley lakes. However, there is an evident persistent rise in the water levels the past decade (Muia et al., 2021). This has therefore called for the intervention of the government and other organizations to help the residents adapt to the new changes since there is little information on whether or not the water levels will keep rising.

In areas like Baringo and Bogoria, schools, hospitals, and other social facilities have been submerged by water hindering the day-to-day activities and forcing the surrounding communities to vacate the area (Muia et al., 2021). The displacement of people results in population pressure in the new settlements which equally result in social issues and conflicts. The government, nongovernmental organizations and other concern stakeholders like Kenya Red-Cross in different institutions play a major role in offering relief services, early warning systems and also help in settling the affected communities, construction of human engineer barriers as well as flood resistant infrastructure such as roads and bridges, zoning of flood prawn areas, channelization among other measures (Nashipay, Mabwoga, & Konana, 2022; Nguma & Kiluva, 2022). However, such help solves the problem temporarily and with consistency of the flood risks, Ecosystem-based approaches (EBA) become the only measure in mitigating the impacts and creating adaptation strategies to the affected communities. Use of EBA strategies involves the incorporation of biodiversity together with the ecosystem to adapt to the occurrences that are linked to climate change.

EBA strategies include the protection of kelp beds and wetlands, agroforestry, afforestation, restoration of coastal areas including mangroves and river banks (Nashipay et al., 2022). The use of EBA strategies to manage floods has been assessed in some areas such as the Upper Suswa in Magadi catchment and have proved to be economically efficient and more flexible to implement compared to the conventional strategies. EBA strategies are multidimensional and multifunction ally efficient in adopting both ecosystem service and biodiversity in mitigating flood risks (Nashipay et al., 2022). In the case of flood mitigation, ecosystem-based adaptation (EBA) strategies have been increasingly implemented as sustainable approaches in the Lake Naivasha catchment. Specific EBA strategies include afforestation and agroforestry, which increase the amount of vegetation cover, decreasing surface runoff, and increasing soil water retention. Wetland restoration helps absorb excess water during heavy rains and rainwater harvesting systems are also a complementary solution. Soil conservation terraces: used to prevent soil erosion and detention basins used to prevent flooding also have been used, providing co-benefits to local communities (Nguma & Kiluva, 2022). This study has assessed the effectiveness of using ecosystem-based, structural, and non-structural strategies to mitigate flood risks on Lake Naivasha catchment.

1.1 Statement of the Problem

The negative impacts of floods caused by climate change are bound to be felt for a long period and therefore different nations have to adopt adaptation strategies that can be trickled down to local communities to mitigate floods (Mugagga et al., 2012). Most of the affected communities face similar impacts and therefore a strategy that has been proven workable for one locality can be adopted by others. Effective flood management strategies, combined with conservation efforts in the catchment area, are essential to mitigate the impacts of floods on the environment and the livelihoods of local communities in the region. Most mitigation measures are applied at the coastal areas when it comes to the lakes while forgoing the entire catchment (Pedersen Zari et al., 2017). Past studies have highlighted various strategies for flood mitigation and their challenges. For instance, Mugagga et al. (2012) emphasized the long-term negative impacts of floods caused by climate change, urging the adoption of adaptation strategies at both national and local community levels. However, most flood management measures focus on coastal areas, particularly around lakes, neglecting the broader catchment areas where floods often originate (Pedersen Zari et al., 2017). Ecosystem-Based Adaptation (EBA) strategies, which restore ecosystems and enhance their services, have shown potential in addressing climate-related challenges such as biodiversity loss and soil erosion. Despite this, limited research has assessed the effectiveness of EBA strategies in mitigating floods within specific catchments. In the context of the Lake Naivasha catchment, research gaps are evident. Existing studies have not comprehensively explored how EBA strategies could reduce flood severity and associated risks. Additionally, there is a lack of integrated approaches addressing entire catchment areas rather than focusing solely on downstream coastal zones. Furthermore, few studies engage local communities or examine the socio-economic benefits of EBA strategies. Comparative analyses of EBA strategies versus traditional mitigation measures are also scarce. Addressing these gaps could provide critical insights into sustainable flood management in regions like the Lake Naivasha catchment.

This research explores the EBA strategies used in mitigating floods in the lake Naivasha catchment. Ecosystem based adaptation strategies are approaches that focus on the restoration of the ecosystem and enhancement of its services to protect the society form the negative impacts of climate change. Mitigation measures have been established but they have not met the objective of flood mitigation, however the assessment of using EBA strategies along the lake Naivasha catchment has not been explored to establish if they can help in mitigating the severity and risks of floods in the catchment.

1.2 Study objective

The main aim of this study was to determine ecosystem-based adaptation strategies for flood mitigation in Lake Naivasha catchment.

II. LITERATURE REVIEW

2.1 Theoretical Review

The theoretical literature review grounds this research in the broader framework of ecosystem-based adaptation (EBA) approaches to flood risk reduction. Environmental flow strategies are often based on climate adaptation, ecosystem management, and sustainability concepts. These approaches fit within theories, such as the socio-ecological systems (SES) theory that focuses on the interconnectedness of human and ecological systems. The link between environmental, and human resilience can be made through SES theory. It claims that ecosystems, provided they are sustainably managed, can provide critical services such as flood mitigation, biodiversity conservation, and climate regulation (Mugagga et al., 2021). Alternatively, you can try a different theoretical framework and the idea behind it, like adaptive management theory and the learning-action approach- an iterative process of learning through action and adapting to changing conditions. This is particularly true for flood-prone areas, where climatic and anthropogenic drivers resulted in highly dynamic hydrological systems. Adaptive management, characterized by flexibility and learning by doing, can motivate communities and stakeholders to increasingly improve various EBA strategies (e.g. afforestation and agroforestry) to prevent flooding (Shah et al., 2019). Furthermore, EBA techniques are related to the resilience theory of ecology, which emphasizes the ability of ecosystems to withstand disturbances and remain functional. Focusing on wetland restoration or building soil conservation terraces, the communities strengthen the resilience of the ecosystem and lessen the exposure to flooding impacts. The theoretical concepts discussed above all derive the justification for the use of EBA approaches in the Lake Naivasha catchment area. At the same time, they highlight the importance of a multidisciplinary approach that integrates ecological health, community participation, and policy support to create sustainable and adaptive flood mitigation measures (Pedersen Zari et al., 2017). This review provides the basis for examining the empirical evidence of EBA effectiveness in the subsequent section.

2.1.1 Socio-Ecological Systems (SES) Theory

The Socio Ecological Systems (SES) Theory focuses on the interactions between human societies and ecological systems through a dimensional approach. According to this theory, healthy ecosystems are crucial for human beings, and the management of ecosystems is essential to address environmental issues such as floods. Under the SES theory, both ecological and social systems are viewed as one unit and as responsive systems that can change structure and functioning in reaction to external or internal perturbations. This theory further stresses on the need of ensuring the ecosystem resilience, which is the capacity to withstand disturbances, change and still provide a range of functions (Cote & Nightingale, 2012). Floods for instance are mitigated by absorbing upland water, stabilizing soil and regulating hydrological cycles, which wetlands and forests ecosystems do best. In connection with areas of Lake Naivasha drainage basin, which are prone to flooding, SES theory emphasizes the need for holistic strategies that incorporate ecological as well as social aspects. For instance, afforestation, agroforestry and wetland restoration activities can be referred to as EBA strategies that satisfy the SES principles by improving environmental conditions and increasing the capacity of the communities to cope with floods. SES theory also highlights the role of individual stakeholders in the management of ecosystem (Virapongse et al., 2026). It accepts that the communities, agencies, and others have to work together in the formulation of active management measures that would be effective considering the climatic and social changes. The possibilities of the socio-ecological systems to adapt, as the theory postulates, are improved through being actively engaged, through learning through doing, and through combining local and scientific knowledge. Using this theory, the study places ecosystem-based flood mitigation strategies within a broader context concerning the prevention of environmental degradation, the improvement of the community, and the adaptability of the climate (Hertz & Schlüter, 2015). That is how this theoretical perspective fulfills its functions in the evaluation of the environmental benefits of EBA strategies in Lake Naivasha and places that target the same objectives.

2.2 Empirical Review

Empirical studies point to the utilization of ecosystem-based adaptation (EBA) strategies for flood-risk mitigation with co-benefits such as better water quality and biodiversity conservation. For instance, in Upper Suswa-Magadi catchment in Kenya, it can be observed that EBA, including agroforestry and afforestation, are cost-effective and flexible alternatives to conventional structural measures (Nashipay et al., 2022). Similarly, South Africa has illustrated that rainwater harvesting hugely contributes to the reduction of urban flooding while providing water resources during dry periods (Busayo et al., 2022). The Lake Naivasha catchment study placed high adoption rates on EBA strategies, such as agroforestry and afforestation, as a means of realising the dual benefits of flood mitigation and carbon sequestration. Policy support from the Kenyan government, such as the Agroforestry Strategy 2020-2030, has further encouraged the implementation of such strategies; however, studies highlighted mulching and cover cropping as less adapted because of knowledge gaps and supply chain limitations in horticulture, which dominantly practises in the area. Other structural measures like rainwater harvesting systems and soil conservation terraces proved successful to mitigate floods, resembling a similar trend observed in the Atlas Mountains of Morocco, where agricultural terraces reduced the runoff and soil erosion which contributed to flood control (Meliho et al., 2021). However, other echoing challenges faced by the whole region include, among others, high costs and maintenance measures to be put in place for detention and retention basins in Lake Naivasha. According to empirical evidence, a lot of community awareness and government intervention are required to scale up the adoption of EBA strategies. Indeed, with the sheltering of floods through declining severity-their strengths-must be weighed against a cost-effect technical know-how on such systems, other land uses opposing this type of practice, and the wide-scale field implementation programs for better promotion.

III. METHODOLOGY

3.1 Research Design

The study employed a descriptive correlational method comprising of combined quantitative and qualitative approaches to comprehensively assess severity of floods in the Lake Naivasha catchment, identify the existing EBA strategies in the catchment and understand their effectiveness in mitigating floods in the catchment. This approach was selected due to the complexity of the research problem. As such, the mixed methods research approach allowed for a comprehensive understanding of the relationship between EBAs and flood mitigation which is the primary problem affecting Lake Naivasha and other Rift Valley lakes. The survey questionnaire included questions designed to elicit participants' knowledge and awareness of EBAs. Participants were asked to identify EBAs they were aware of and to suggest additional strategies that could be implemented. The ecosystem-based adaptation strategies constituted another categorical independent variable for the various EBA techniques identified such as afforestation, reforestation, and wetland restoration, among others.

3.2 Study Area

Lake Naivasha is located on the floor of Africa's Eastern Rift Valley and lies within an area of approximately 3250 km^2 during the wet season (Otiang'a-Owiti & Oswe, 2007). It is located at Latitudes 0^0 41' 0" S and 0^0 50' 0" S and Longitudes 36^0 17' 0" E and 36^0 26' 0" E. Lake Naivasha catchment geographical location is mainly distinguished by Kinangop Plateau and Eburru Hills as it lies between these physical features. At roughly 1,890 metres (6,200 feet) above sea level, it is situated in a distinctive area of the Rift Valley system. The catchment experiences an equatorial type of climate comprised of two rainy seasons and a dry season. The rainy seasons are experienced between April and May, then September and October while the dry season in December, January and February.

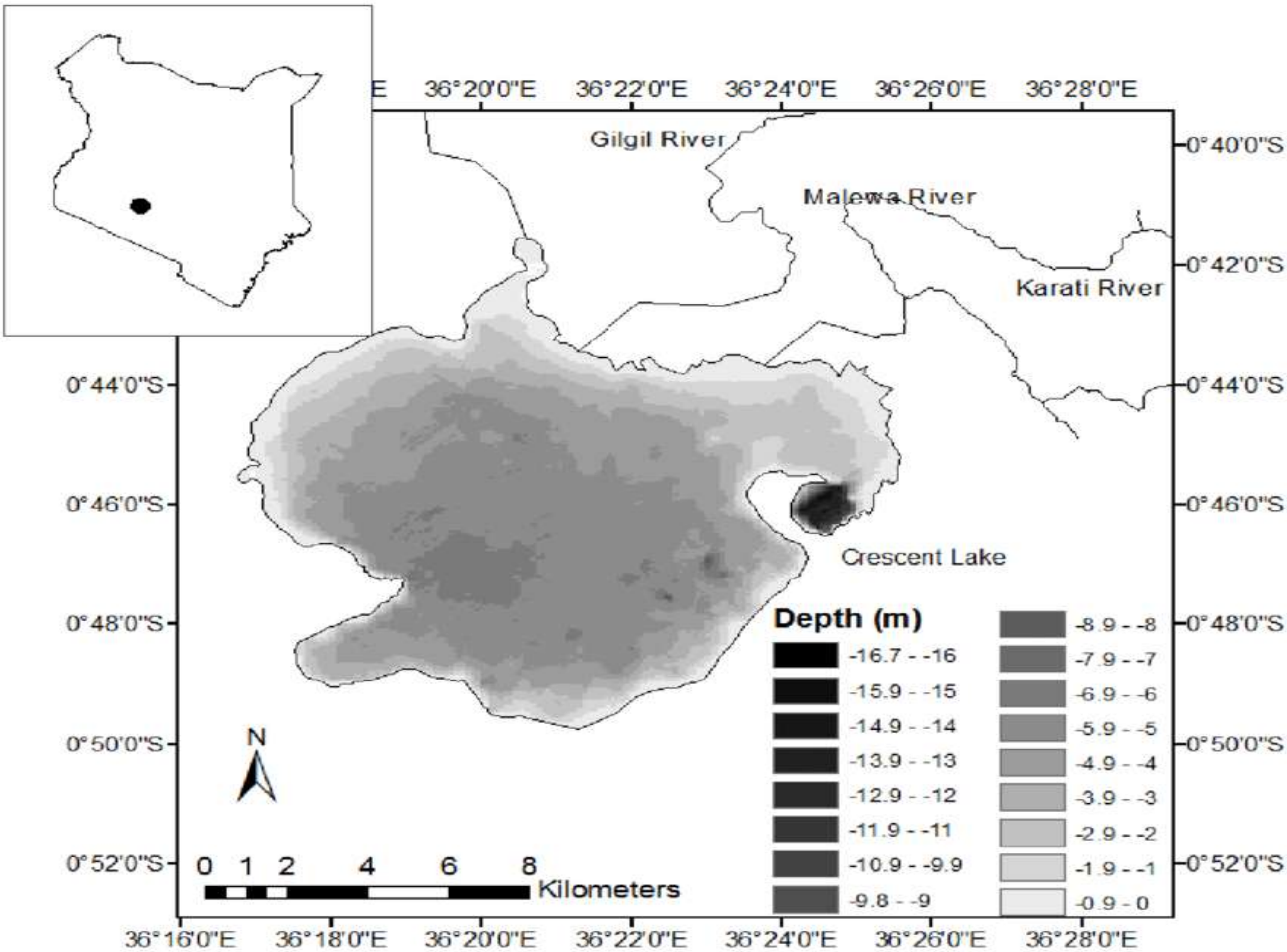

Figure 1
Map of Lake Naivasha Catchment

3.3 Target Population

This study targeted the households in the Lake Naivasha Catchment which included households in the upper, middle and lower parts of the catchment. This included parts of Karati, Lake View, lake Naivasha, Malewa, and Sokoni areas. These areas are characterized by different population as shown in table 1 based on the 2019 Kenya Bureau of Statics (KNBS) Census conducted in 2019. The total number of households in the stud area was approximated to be 29,190 as indicated in table 1.

Table 1
Population of the Study Area

Area		Sex			Households	
	Total	Male	female	Total	Conventional	Group Quarters
Karati	11,363	5,789	5,574	3,521	3,303	218
Lakeview	39,286	19,157	20,115	13,688	13,640	48
Malewa	11,296	5,853	5,442	3,993	3,993	-
Lake Naivasha	21	15	6	9	9	-
Sokoni	21,562	10,486	11,074	7,979	7,979	-
Total				**29,190**		

3.4 Sample Size and Sampling Procedures

The study population comprised residents of the Lake Naivasha catchment, including farmers, fishermen, tour guides, and other individuals directly or indirectly affected by flooding. The respondents to household questionnaires were selected randomly from a random frame list of about 29190 households of residents in the catchment. The sample size was calculated using the Yamane (1973) formula as cited in Kuswanto et al. (2020) for finite population formula shown in Equation 1:

$$n = \frac{N}{1+N.e^2)} \qquad (1)$$

Where;

n= sample size

N= population size (29,190 for Lake Naivasha catchment)

e = standard error (0.05).

$$n = \frac{29190}{1+29190\times0.05^2)}$$

n= 395

The house-hold sample size was computed as a proportion was calculated as in equation 2

$$x = n \times \frac{Q}{P} \qquad (2)$$

Where

x= proportion

n= sample size

Q= area population

P= total population

Table 2

Sample Size per Area

SN	STUDY AREA	HOUSE HOLD	SAMPLE SIZE
1	Karati	3,521	47
2	Lake view	13,688	185
3	Malewa	3,993	54
4	Lake Naivasha	9	2
5	Sokoni	7,979	107
6	Key stakeholders from different organizations such as administration, WRA, KMD, county Agriculture officers, NEMA, and Kenya Red Cross – 6 **Total**	**29,190**	**395**

3.5 Data Collection Procedures

Primary data was collected through structured questionnaires, key informant interviews, and focus group discussions. Table 3 shows a summarized matrix of the study objective

Table 3

Summarized Matrix for the Study Objective

Research objective	Data variables	Data sources	Data collection method	Data analysis method
Determine ecosystem-based adaptation strategies for flood mitigation in lake Naivasha catchment.	Afforestation Agroforestry Wetland Restoration Minimum and Zero Tillage Cover Cropping Mulching Rainwater Harvesting Soil Conservation Terraces Detention Basins Retention Ponds	FGD KII	Interviews Questionnaires	Descriptive Analysis (Excel, mean and standard deviation)

3.6. Ethical Considerations

The study received ethical approval from Masinde Muliro University of Science and Technology and a research permit from the National Council of Science, Technology, and Innovation (NACOSTI). The researcher further sought permission from the respective County Commissioners and County directors of education, fisheries, agriculture, and environment before carrying out the study. Participants were informed about the study's purpose and their voluntary participation. Confidentiality and anonymity were ensured through the use of coded identifiers and the secure storage of data.

IV. FINDINGS & DISCUSSION

4.1 Ecosystem-Based Adaptation Strategies for Flood Mitigation in the Lake Naivasha Catchment Area

The study sought to identify the structural, non-structural, and any other existing EBA structures for flood mitigation in the Lake Naivasha catchment.

4.1.1 Structural and Non-structural EBA Strategies

These EBA strategies in the catchment were categorized into two i.e. structural and non-structural. The non-structural strategies identified in the study included wetland restoration, afforestation, agroforestry, mulching, cover cropping, and minimum and zero tillage. On the other hand, the structural measures identified were rainwater harvesting, retention ponds, detention basins, and soil conservation terraces (Table 4).

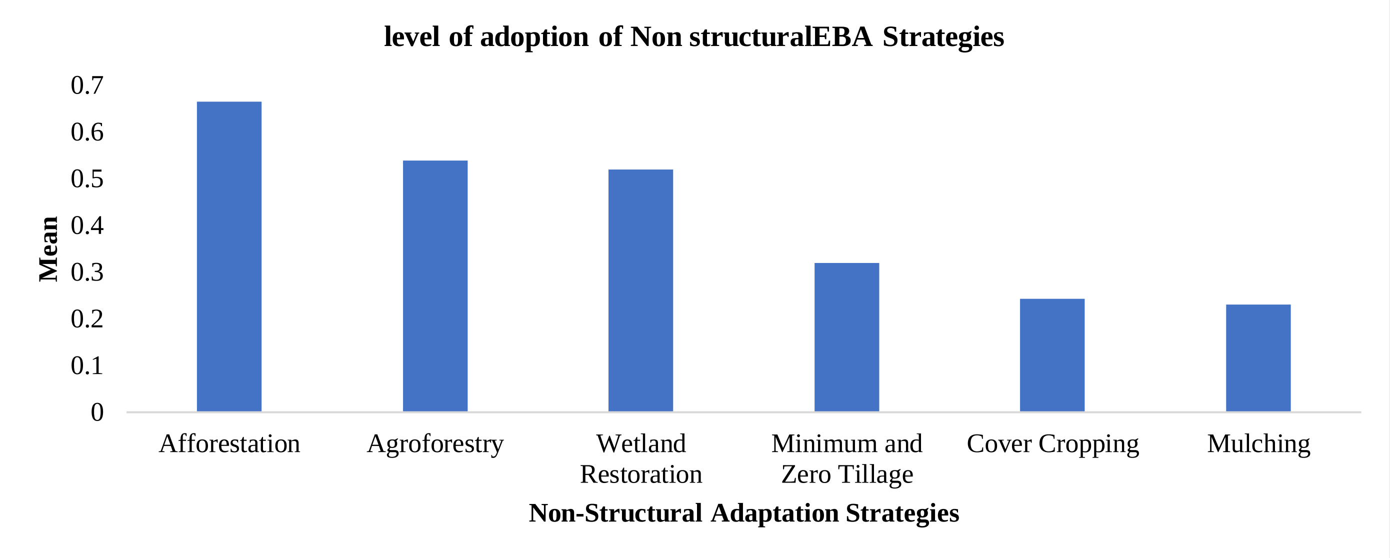

Figure 2
Level of Adoption of Nonstructural EBA Strategies among Study Participants

Based on the study findings in figure 2, the following are the common non-structural EBA strategies used in the Lake Naivasha catchment area; afforestation (M = 0.6642, SD = 0.0262), agroforestry (M = 0.5385, SD = 0.0277) where M is the mean and SD is the standard deviation. According to studies (Akamani & Holzmueller, 2017; Matocha et al., 2012; Shah et al., 2019), incorporating agroforestry and afforestation in mitigating the effects of climate change is easily adopted because the trees have several co-benefits including but not limited to carbon sequestration, economic benefits together with aesthetic and environmental management approaches. The Kenya government has equally supported agroforestry and agroforestry through its provision of favorable agroforestry policies and formulation of the agroforestry strategy 2020-2020 (Mumina & Bourne, 2020). The Kenyan President has severally declared and gazetted public holidays for tree planting to help in mitigating the negative impacts of climate change such as floods. The recent public holiday was on May 10th, 2024 (Koko, 2024). These holidays have had different organizations, institutions, and individuals participate in national tree planting hence increasing the adoption rates of the strategies and this corroborates with the findings by Selman (2004).

According to one respondent, it is easier for everyone to practice afforestation and agroforestry because of the government policies that support the activities. They stated that the government supports growing of trees and each person was willingly growing trees on their farms and homesteads. One respondent from the FGDs stated;

> *"Every person grows trees in their homesteads willingly and even our president has gone further holding public holidays just for planting trees. You will not fail to get a homestead with no trees and also trees have economic impact, environmental conservation benefits among others. These are the reasons why we are growing more trees."*

While agroforestry and afforestation are gaining a lot of relevance as EBA strategies in flood mitigation in the catchment, the use of mulching and cover cropping as EBA strategies were least adopted in the catchment with cover cropping having (Mean = 0.2431, SD = 0.0238) and mulching (M = 0.2308, SD = 0.0234) respectively. Research done by (Srivastava, Basche, Traylor, & Roy, 2023) indicated that mulching and cover cropping are conservation practices that have played a major role in flood reduction and improvement in water quality. The conservation practices reduce the amount of runoff causing erosion and allowing much time for infiltration. The practices also conserve the amount of moisture in the soil which is essential for crop production. Adoption of this practises is however limited to the type of crops being produced and the amount of mulch to apply which is linked to the knowledge of the application process (Srivastava et al., 2023).

Most of the respondents agreed to not having enough knowledge in mulching and cover cropping. To others, mulching and cover-croping are primarily used as soil moisture conservation measures. According to one farmer in the FGDs , horticultural farming does not involve much use of cover crops and mulches;

> *"In Naivasha most of the agricultural practices are horticultural and therefore done in greenhouses. We only follow instructions given for crop management while serving in the greenhouses and very little is being done with regards to mulching and cover cropping."*

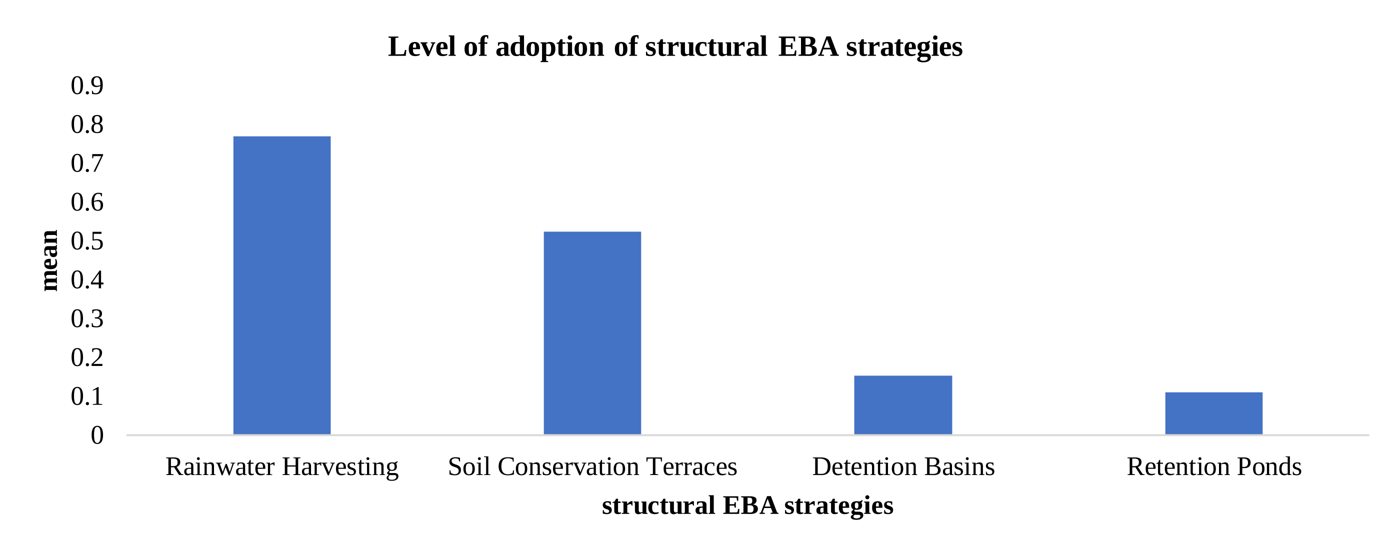

Figure 3
Level of Adoption of Structural EBA Strategies

According to this study, there was existence of structural EBA strategies with rainwater harvesting (M = 0.7692, SD = 0.0234), soil conservation terraces (M = 0.5231, SD = 0.0278) being the highly adopted measures as in figure 3. Research done in South Africa indicated that the use of rainwater practices helped in mitigating floods that had severe impacts between 1959-2019 (Busayo et al., 2022). Rainwater harvesting has helped in managing urban floods where water harvesting tanks are distributed to help reduce the impacts of small to medium flooding events (Jamali, Bach, & Deletic, 2020). The Kenyan government in collaboration with other stakeholders including donor funding and non-governmental organizations among others, have also invested a lot in rainwater harvesting structures such as water pans, earth dams, and rainwater storage as evident in the National Water Harvesting and Storage Strategy 2020-2025 (Muthee et al., 2021).

Soil conservation terraces were also well adopted since most of the farmers use the same practice as a form of conservation agriculture strategy in soil and water conservation. According to the research done in the Atlas Mountains in Morocco, it was easier to use agricultural terraces in mitigating floods since majority of the farmers had the knowledge and the structures in place this contributed to the reduction of flood occurrence (Meliho, Khattabi, Nouira, & Orlando, 2021). A farmer from the FGDs highlighted that it was easier for most farmers to use soil conservation terraces in flood mitigation and they have seen their significance in managing soil erosion hence flood mitigation becomes a co-benefit.

> *"In my farming practices, I have used soil conservation terraces to manage soil erosion on my farm. These terraces have significant importance such as temporal water storage structures, soil erosion control measures and now flood mitigation measures."*

The use of detention basins (M = 0.1239, SD = 0.0200), and retention ponds (M = 0.1108, SD = 0.0174) were the least adopted structural measures in this study. Retention ponds and detention basins are water-filled pools used to regulate the flow of runoff by retaining runoff water and releasing it slowly to reduce the occurrence of floods. A study done in central Belgium to investigate the spatial-variation of flood occurrence and muddy floods in rural areas indicated that the retention ponds and detention basin helped in controlling floods (Verstraeten & Poesen, 1999). The study indicated that the major challenge hindering the adoption of retention ponds and detention ponds was the cost of construction, dredging, and general maintenance of the structure.

Most farmers in the Lake Naivasha catchment did not know the retention ponds and detention basins and their existence in the catchment. Those who had the idea of their existence complained of the high cost of construction, maintenance costs, and also stated that the structure occupied land that could be used for other purposes. One farmer from the flower farm FGDs highlighted that the ponds contributed to malaria and other water-borne diseases.

> *"The ponds are great structures when mitigating floods but require land space which we can be used to produce crops or other purposes. The cost of construction and maintenance is high and we would wish the government to intervene. "*

Out of 325 responses, 286 participants were not aware of other adaptation strategies, while 39 identified additional strategies implemented at the catchment as follows; Building gabions, Construction drainage systems, development of terraces along the riverbanks, and establishment of city green spaces (Structural). The other proposed non-structural structures included; relocation of wildlife, clearing drainage systems, establishment of tree nurseries, sewage treatment, and conservation and reclamation of the water resources and wildlife reserves.

4.1.2 Occupation and Awareness of EBA Strategies in the Catchment

The study also aimed to examine the relation between the participants' occupation and its relationship to the awareness of EBA strategies. Participants in different occupations had different perceptions of EBA strategies while others had little knowledge about EBA strategies. Table 4 shows the percentage representation of the respondents' awareness of the different EBA strategies.

Table 4
Occupation and Level of Perception in Percentages

Strategy	Occupation and level of perception in percentages					
	Farmer	Environmentalists	Fishermen	Business people	Employees	Others
Afforestation	46.59	57.81	10.22	40.44	16.8	12.44
Agroforestry	57.79	57.81	10.05	42.51	22.43	16.55
Wetland Restoration	22.32	30.18	46.44	6.46	0.58	0.52
Minimum and Zero Tillage	42.34	45	8.44	4.01	6.43	0
Cover Cropping	10.12	15	5.32	2.02	4.66	0.39
Mulching	10.34	12.01	6.48	2.11	4.31	0.27
Rainwater Harvesting	58.24	56.44	28.97	58.24	22.03	16.97
Soil Conservation Terraces	48.88	44.06	14.56	32	10.55	6.22
Detention Basins	2.02	8.32	0.57	0.29	0.88	0
Retention Ponds	2.38	10.56	0.36	1.08	0.59	0

The analysis also included a chi-square test used to analyze categorical variables to examine any significant differences between occupation and awareness of ecosystem-based strategies among participants. There was a significant difference in awareness of two strategies by occupation: wetland restoration (p-value = 0.00164) and soil conservation terraces (p-value = 0.00133). There is no significant difference between occupation and awareness of ecosystem-based strategies for the other strategies in the study at the 95% confidence level.

The occupation groups with the highest number of individuals aware of these two strategies were environmentalists who had 30.18% of respondents aware of wetland restoration, and farmers who had 48.88% of respondents aware of soil conservation terraces. Further, 57.81% of respondents were aware of afforestation and agroforestry (environmentalist), and 58.24% of respondents aware of rainwater harvesting were farmers and business owners. These three groups potentially had higher education levels and specific experience than the other groups in the sample which included farmers, business people, fishermen, tour guides, and those in other informal occupations). Consequently, their education levels and business affiliations potentially exposed them to these strategies, resulting in higher awareness levels. Farmers and environmentalists had a lot of knowledge on EBA strategies due to their day-to-day interactions with the strategies as they directly benefit from the co-benefits that come with their uses. For instance, the use of agroforestry, afforestation, soil conservation terraces to manage soil erosion also helps in mitigating flood risks and general environmental management.

4.1.3 Effectiveness of these Strategies in Reducing Flood Impacts in Lake Naivasha Catchment

The research findings pointed out those ecosystem-based adaptation strategies were quite effective in reducing the impacts of floods within the Lake Naivasha catchment. Non-structural strategies like afforestation and agroforestry proved to be highly effective, with 81.87% of the participants stating that floods were reduced. This is especially so because afforestation and agroforestry are quite effective in increasing vegetation cover; hence, the soil water retention capacity increases, reducing the surface runoff. Moreover, the restored wetlands absorbed excess water at times of heavy rainfall and, therefore, acted as a natural barrier to floods. On the other hand, structural measures such as rainwater harvesting and soil conservation terraces were widely adopted and very effective. Rainwater harvesting systems managed urban runoff and provided storage, while terraces reduced soil erosion, hence indirectly controlling flooding. However, the adoption of strategies such as detention basins and retention ponds remained low, mainly due to high installation and maintenance costs, in addition to land space limitations. Overall, EBA strategies demonstrated co-benefits such as improved water quality, enhanced biodiversity, and strengthened community resilience. The study emphasized the important role of community awareness, government support, and the integration of both structural and non-structural measures to have sustainable flood mitigation in the catchment.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

From the study, the highly adopted non-structural EBA strategies were afforestation and agroforestry due to their co-benefits and government support while the least were mulching and cover cropping due to insufficient knowledge on the application methods. On the other hand, the highly adopted structural EBA strategies were soil and water conservation terraces and rainwater harvesting structures due to their co-benefits and government interventions while the least adopted were retention ponds and detention basins due to the high cost of installation and maintenance. Most of the environmentalists and the agriculturalists had better knowledge of EBA strategies compared to other respondents from other professional fields.

5.2 Recommendations

The recommendations made from the findings of the study include: More research should be done to understand other flood mitigation measures to help reduce the impacts of severe floods in the catchment, awareness creation among more community members regarding EBA strategies, their effectiveness in flood mitigation and how the community members can participate at the individual and community levels in adopting these strategies. Equally, active governmental involvement in flood mitigation may be beneficial in promoting the implementation of EBA strategies on a larger scale. The observed positive changes and perceived effectiveness suggest that EBA strategies can be a valuable tool for flood mitigation in this region. However, addressing the identified challenges is essential for maximizing the potential of these strategies and ensuring their long-term success.

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